Abstract

The increasing demand for space cooling presents a pressing challenge in achieving sustainability goals, particularly the target of net-zero emissions by 2050. In this context, district cooling represents a feasible alternative to conventional cooling technologies, especially in densely populated areas. Larger industrial chillers used in district cooling networks are indeed characterised by better performances, compared to the smaller residential ones. Moreover, the non-contemporaneity of demand peaks makes the load of district cooling networks more homogenous than the one of a single building. As a consequence, if on one hand residential chillers are usually oversized and tend to work at lower loads with worse performances, on the other hand the centralized chillers of a district cooling network are properly sized and operate more uniformly with better performances. In addition, further energy savings can be achieved by integrating this technology with renewable energy technologies or waste heat from industrial plants. Moreover, the integration with thermal energy storage in the context of power-to-cool strategies can reduce the pressure on the grid while lowering the operation costs, thanks to lower electricity tariffs during off-peak hours. On the other hand, the diffusion of this technology is strongly affected by the higher pumping and piping costs, due to the large mass flow rates required. Optimization tools are therefore necessary to fully exploit the potential of district cooling. This thesis hence focuses on the development and implementation of novel optimization models for the design and operation of district cooling networks, with the goal of enhancing the potential of this technology. Initially, a simplified optimization problem is defined, which is gradually made more complex in the rest of the thesis, with the goal of taking more aspects into account. The initial problem consists in optimizing the network layout, building connections, and pipe diameters for a single-plant network, minimizing the sum of operation and capital costs while considering pressure drops and pumping costs. A Mixed Integer Linear

Programming (MILP) model and a genetic algorithm have been implemented to tackle this problem.

The first additional complexity consists in considering the uncertainty of cooling demand and cost parameters, optimizing both the initial network design and possible future expansion by means of a two-stage stochastic programming model. The second problem complexity involves considering thermal energy storage and multiple plants, optimizing their positions and the buildings connected to the network. A genetic algorithm was implemented to address a simplified version of this problem with a fixed storage strategy, while a Mixed Integer Quadratic Programming (MIQP) model was implemented to optimize the cooling power dispatch, fixing the building connections. The two models were also compared to evaluate the impact of optimizing simultaneously both design and operation.

The final problem formulation includes additional decision variables such as the storage technology to be installed and the network supply temperature, considering its impact on chiller efficiency, piping, and pumping costs. A hierarchical model integrating a genetic algorithm with MILP models has been developed for this purpose. All the implemented models have been applied to real or realistic case studies to evaluate the potential of district cooling and determine the conditions for economic viability in Mediterranean and tropical urban contexts.